Moral Hazard in a model of Bank Run with Noisy Signals

J.Boonprakaikawe and S.Ghosal[1]
Department of Economics, University of Warwick

January 13, 2003

[1]We would like to thank Marcus Miller, Jonathan Thomas, Myrna Wooders and the seminar audiences at the Asian Crisis III conference in Tokyo and CSGR(Warwick) for their valuable comments. The first author would like to acknowledge the Thai Government and the CSGR, University of Warwick for financial support. Please address all correspondence to: J. Boonprakaikawe, Department of Economics, University of Warwick, Coventry CV4 7AL, e-mail: J. Boonprakaikawe@warwick.ac.uk

Abstract

We show that multiple equilibria exist in a model of bank run with moral hazard. Furthermore, this is true even with noisy signals on the economic fundamentals. We argue that the conditions under which this happens can arise naturally in models of banking with moral hazard problem.

Key Words: banking, fundamentals, signals, equilibria. JEL classification: D80, D82, G21.

Approximate word count: 7500

1 Introduction

We investigate the conditions under which multiple equilibria due to coordination failure can be ruled out when individual agents have noisy signals about the fundamentals of an economy. Morris and Shin (1998) apply the idea of Carlsson and van Damme(1993) to a model of currency crisis where, with common knowledge of fundamentals, self-fulfilling currency attacks lead to multiple equilibria. They show that even a small amount of noise about fundamentals yields a unique equilibrium[1]. The insights generated by their paper extends to other market situations where multiple equilibria may exist due to coordination failures. These insights present a major challenge to any attempts that seek to explain either currency attacks (as in Obstfeld (1986)) or bank runs (as in Diamond-Dybvig (1983)) using models with self-fulfilling multiple equilibria. Indeed, Jeanne and Masson (2000), using a model with multiple equilibria to study the experience of the French franc from 1987-1994, explicitly acknowledge the criticism of their approach implied by the uniqueness result in Morris and Shin (1998).

Our purpose here is to address this challenge to models with self-fulfilling multiple equilibria by studying the robustness of the uniqueness result with noisy signals about fundamentals.

We change the original context of Morris and Shin (1998) paper from currency crisis to banking. Ever since Diamond and Dybvig's seminal (1983) paper, the phenomena of bank runs arising out of coordination failure has been extensively studied[2]. Subsequently, several authors have applied the methodology developed by Morris and Shin (1998) to models of banking (see for example, Goldstein and Pauzner (2000), Morris and Shin (2000)).

A key assumption in Morris and Shin (1998) applied to models of banking is that with complete information, the space of fundamentals can be partitioned into three non-empty subsets, an unstable region where the bank always fails, a middle region in which there is multiple equilibria and a stable region where the bank always survives. Assuming all three regions are non-empty, a small noise in the observation of the true value of the fundamentals, implies that it can never be common knowledge that fundamentals are in the middle region. It is this feature that is crucial for the uniqueness result in Morris and Shin (1998) to go through. Both Morris and Shin (2000) and Goldstein and Pauzner (2000) show the existence of a unique equilibrium with noisy signals on fundamentals with this assumption.

Here, in contrast, we do away with the assumption that all these regions are non-empty and show that multiple equilibria exist even with noisy signals on the fundamentals of banking. In section 4, we study two different cases where this assumption no longer holds. In the first case, we assume that both the stable and the unstable regions are empty. In this case, even with noisy signals on fundamentals, it remains common knowledge that these fundamentals are in the middle region. From this it follows that both bank runs and bank survival continue to remain equilibrium outcomes. This case serves as a useful benchmark for our main result. In order to prove this result, we investigate the less restrictive case when only the stable region is assumed to be empty. In this case, even with noisy signals on fundamentals, it remains common knowledge that the fundamentals lie in either the unstable or in the middle region. Under this assumption, we show that when the fundamentals fall below a certain critical value, the bank always fails, but above that same critical value, both

[1] For further applications of this uniqueness result, see Corsetti, Morris and Shin (1999) and Morris and Shin (2001a, 2001b).

[2] See for instance Freixas and Rochet (1998) and the references contained therein.

self-fulfilling bank runs and bank survival remain equilibrium outcomes.

Is the case with an empty stable region economically relevant? First, we examine the optimal decision of banks when faced with a potential collapse and derive endogenously the assumption of an empty stable region. When the proportion of early withdrawal is high, a bank may decide to defend itself by liquidating some of its long-term assets or borrowing from the outside third party to pay for withdrawal demand. We will argue that because of the problem of moral hazard, mis-management is not observable at least for a short time period. This means that the outside third party may not be able to distinguish between a bank that is facing a liquidity problem and a bank that is mis-managed. Any outside third party considering lending to troubled banks may ask for a high loan rate, imposing costly conditions or even ration out loans. Under these circumstances, we show that banks will decide to collapse regardless of fundamentals when (a) the credit rationing in the market for bank loans is severe, or (b) the cost of bank loans is high. In all these cases, the stable region is empty.

It is important to distinquish the point we make here from other criticism that gives rise to multiple equilibria, for example, the introduction of public signal. Atkeson (2000) in his discussion of Morris and Shin paper argues that publicly observed market prices, if priced in equilibrium, can serve to coordinate agents' action because they aggregate information across all individuals thus revealing which equilibrium will actually occur. Boonprakaikawe and Ghosal (2002) and Hellwig (2000) also show, via introducing relatively informative public signals, that the result of Morris and Shin is not robust and multiple equilibria are maintained. Contrast this to our paper where we will show that even without the possibility of publicly observed signals, e.g. when market prices fail to predict a crisis or reveal sufficient information about the fundamentals, multiple equilibria can still arise in a model of banking with noisy signals.

Second, a minimum size of the bank which is bounded away from zero can also be justified if the bank's asset portfolio has illiquid assets. By reinterpreting fundamentals to represent an exogenous liquidity shock, we show that our model of banking can be derived as a reduced form version of Diamond and Dybvig (1983)'s model of banking where the proportion of illiquid assets is derived endogenously. Finally, we show that the assumption on the minimum size of the bank follows from the analysis of Goldstein and Pauzner (2000)'s model of banking with risk-sharing when the sources of external and internal finance available to the bank are limited.

In the final section of the paper, we discuss some empirical and policy issues that arise from our analysis. One implication of Morris and Shin (1998) (see also Morris and Shin (1999a)), is that the onset of a crisis should be anticipated as the fundamentals evolve to approach the critical value needed to trigger a speculative attack. On the other hand, our main result implies that a financial crisis should be largely unanticipated by markets. In fact, a wide array of empirical papers that supports the view that episodes of financial and currency crisis are largely unanticipated. A related issue is on the role of policy interventions that prevent a crisis. Our main result here suggests a role for policy interventions that coordinate the expectations of traders on the "right" equilibrium. In contrast to Morris and Shin (1998), our results suggest that suspension of convertibility, restrictions on capital flows, lenders of last resort can be rationalized as policy interventions that prevent runs due to self-fulfilling expectations.

In the next section we present a model of banking with moral hazard and show that self-fulfilling multiple equilibria can exist. Section 3 enriches the analysis by allowing random state of nature. Section 4 relaxes the assumption of perfect information, letting the signals observed on the fundamentals to contain a noise error. Then, in section 5, we show that even with noisy signals, there can exist multiple equilibria in models with moral hazard problem. In section 6, we compare our banking model to that of Diamond and Dybvig (1983) and Goldstein and Pauzner (2000). Section 7 discusses empirical and policy issues. The last section concludes.

2 The model

In our model, a bank is a financial intermediary whose existence results from its acquirement of specific skills in monitoring investment projects (entrepreneur). It borrows from both equity holders and depositors. For simplicity and without loss of generality, assume that equity is used to financed the fixed cost of setting up a bank. The return on equity depends on the investment return while the depositors held a demand deposit contract similar to that of Diamond and Dybvig (1983) with sequential service constraint. Thus, withdrawal demand is serviced on a first come first served basis with late depositors receiving nothing in a case of bank failure. There are three time periods, $t = 0, 1, 2$. Assume that there are a continuum of depositors and equity holders, indexed by i and j respectively, each of Lebesgue measure 1. A single individual is endowed with one unit of the perishable good at time period $t = 0$. Note that in this model, equity holders are included essentially to simplify the analysis and we do not consider their role actively [3].

Depositors preferences are identical and are summarized by the utility function $U_D(x_0, x_1, x_2) = x_1 + x_2$. A deposit contract specifies a return of $R_1 > 1$ in period $t = 1$ and $R_2 > R_1$ at $t = 2$ when one unit of endowment is deposited at $t = 0$. Investment projects financed through deposits can be described as a non-convex technology that converts the inputs of the perishable good at $t = 0$ to outputs of the perishable good at $t = 1$ or $t = 2$. One unit of input yields $\rho(1-\alpha)$, $\rho < 1$ at $t = 1$ and $r(\alpha, e)$ at $t = 2$ where α is the proportion of investment left to $t = 2$ and e denotes action or effort of bank's manager. $r(\alpha, e)$ is assumed to be continuous and strictly increasing in both arguments. Notice that there is a mismatch of liquidity between the deposit contracts and long-term investment technology, this essentially is the cause of financial fragility in our model.

The order of events is as follow, at $t = 0$, the bank is set up through equity finance. Then depositors are assumed to invest all their endowment in the bank. Together with manager decision on the level of effort, the deposits are used to financed investment projects. At $t = 1$, effort creates a cash reserve of $\hat{C}$ stochastically dependent on the level of effort with probability distribution $\Phi(\hat{C}|e)$ (and density $\phi(\hat{C}|e)$) exhibiting an increasing strict monotone likelihood-ratio property (MLRP). A proportion of deposit (liquidity shock) $k, 0 \leq k \leq 1$ then decide to withdraw from the bank. The bank will first service the withdrawal demand with its cash reserve $\hat{C}(e)$. For simplicity we assume that the cost of liquidation is too high compare to the cost of borrowing and thus the bank will always choose to borrow from an outside third party which leaves α equal to one. The cost of borrowing is denoted by $c(\gamma)$ where γ represents the amount borrowed which is equal to $k - \hat{C}(e)$. Also in this period, the manager may decide to liquidate the bank if the utility he receives is lower than his

[3] Without whom, the return on demand deposit contract can be assumed to be increasing in investment return to make the accounting balance sheet of the bank balanced. Note that the overall result will carry through.

participation value $\overline{H}$[4] in which case there will be no borrowing and investment projects will be liquidated. Depositors who are early to withdraw receive R_1until all the cash reserve plus liquidation value, $\hat{C}(e)+\rho$ run out. Late depositors or those who wait until $t=2$ (and equity holder) get nothing, assume $\hat{C}(e)+\rho<R_1$. At $t=2$, if the bank does not fail, the return on production, $r(1,e)$ will first be used to repay loans. Then it will be used to repay depositors while the bank's manager receives a wage dependent on return, a penalty dependent on the amount that bank owes to the lender and a disutility from effort. He has utility function $G(r,-c,e)$ restricted to equal to $U_1(r(1,e))+U_2(-c(\gamma))-V(e)$,[5]. Note that when $k\leq\hat{C}(e)$, the bank do not have to borrow and the utility of the manager is $U_1(r(1,e))+U_2(\hat{C}(e)-k)-V(e)$. U_1 and U_2 is assumed to be increasing concave function while V an increasing convex function. He also has a participation value of H. Lastly, equity holders received the rest of the return.

With non-observable effort and liquidity shock, there is a moral hazard problem with regard to lender's objective in maximising her profits $c(\gamma)-\gamma$. Assuming that the lender is risk neutral with utility $c(\gamma)-\gamma$[6], this is a principal agent problem in the following form,

$$\max_{c(\gamma),e} E\{c(\gamma)-\gamma\}$$

$$\text{subject to}\quad E\{U_1(r(1,e))+U_2(c(\gamma))-V(e)\}\geq H$$
$$e\in\max\arg E\{U_1(r(1,e))+U_2(c(\gamma))-V(e)\}$$

Suppressing $\hat{C}$ and viewing γ as a random variable with a distribution $F(\gamma|e)$ with density $f(\gamma|e)$. The second constraint, the incentive compatibility condition, can first be solved with the first order condition, the above yields

$$\max_{c(\gamma),e}\int_{\gamma\in(0,\overline{\gamma}]}[c(\gamma)-\gamma]f(\gamma|e)\,d\gamma \tag{1}$$

$$\text{subject to}\quad U_1(r(1,e))+\int_{\gamma\in(0,\overline{\gamma}]}U_2(-c(\gamma))f(\gamma|e)\,d\gamma-V(e)\geq H \tag{2}$$

$$r_e(1,e)\,U_1'(r(1,e))+\int_{\gamma\in(0,\overline{\gamma}]}U_2(-c(\gamma))f_e(\gamma|e)\,d\gamma=V'(e) \tag{3}$$

where $\overline{\gamma}$ is an upper bound on the amount of borrowing[7]

Let λ and μ be the multiplier for participation constraint and incentive compatibility constraint respectively. Given that the first order approach is valid[8], a necessary condition for the transformed principal-agent problem is

$$\frac{1}{U_2'(-c(\gamma))}=\lambda+\mu\frac{f_e(\gamma|e)}{f(\gamma|e)} \tag{4}$$

[4] Note that the existence of the bank require a continuity of manager effort.

[5] The penalty on the amount owed can be think of as a wage reduction or other forms of penalty, such as a cost to reputation and future carreer prospect.

[6] The lender can also be assumed to care about the level of production $r(1,e)$, maybe because it is the central bank or the IMF. This does not effect our conclusion of increasing cost of borrowing.

[7] This can be set equal to ∞ or $\overline{\gamma}\in[0,\infty)$ reflecting possibly lender's endownment.

[8] See Jewitt (1988) for details.

From the fact that $f(\gamma|e) = \frac{d}{d\gamma}F(\gamma|e) = \frac{d}{d\gamma}(1-\Phi(k-\gamma|e)) = \phi(k-\gamma|e)$[9]. Recall that the distribution $\Phi(\hat{C}|e)$ has a MLRP. Specifically, the likelihood-ratio $\left(\frac{\phi(\hat{C}|e)}{\phi(\hat{C}|\acute{e})}\right)$ is monotone in $\hat{C}$, increasing if $e > \acute{e}$. Therefore, $\frac{d}{d\gamma}\left(\frac{f(\gamma|e)}{f(\gamma|\acute{e})}\right) = \frac{d}{d\gamma}\left(\frac{\phi(k-\gamma|e)}{\phi(k-\gamma|\acute{e})}\right) = \frac{d}{d\hat{C}}\left(\frac{\phi(k-\gamma|e)}{\phi(k-\gamma|\acute{e})}\right)\frac{d\hat{C}}{d\gamma} < 0$. This also implies that $\frac{f_e(\gamma|e)}{f(\gamma|e)}$ is decreasing in γ, see proposition 5 in Milgrom (1981). This condition is intuitive as it means that higher effort increases the likelihood that the amount of borrowing needed is low. Using a similar argument as in Jewitt(1988), the multiplier μ can be shown to be positive, this is shown in appendix A. Therefore, the right hand side of 4 is decreasing in γ implying that $c(\gamma)$ must be increasing in γ.

2.1 The minimum size of the bank

In this subsection, we will show that $c(\gamma)$ increasing in γ implies that there exists a minimum size of deposits remaining such that the bank will fail if the amount of deposits remained is lower than that minimum size or it will continue to be in business until $t = 2$ otherwise. The minimum size requirement denoted by $a = 1 - \overline{k}$ where $\overline{k}$ is k such that

$$U_1(r(1, e_m)) + U_2(-c(k - \hat{C}(e_m))) - V(e_m) = H$$

where e_m is the level of effort which solves the optimisation problem.

When $k > \overline{k}$, $c(\gamma)$ increasing in γ ensure that the cost of borrowing is increased which in turn leads to lower utility gained for bank manager. Indeed, this will be lower than H and the bank will fail. On the other hand, when $k \leq \overline{k}$, the cost of borrowing will be lowered such that the manager's participation constraint is satisfied and the bank survives. Notice that the proportion of deposits withdrawn k can be thought of as partly endogenous. If depositors suspect that k is likely to be greater than $\overline{k}$ then many more depositors will withdraw which will increase k itself, in our model, everyone will withdraw, $k = 1$, as they are homogenous. This situation infact describes a multiple self-fulfilling equilibria where a belief that the bank will fail will indeed lead to its failure and vice versa. Also, notice that because $c(\gamma)$ is increasing in γ, $\overline{k}$ is decreasing in H and a is increasing in H.

In addition, when $k \leq \hat{C}(e_m)$, $\overline{k}$ is k such that

$$U_1(r(1, e_m)) + U_2(\hat{C}(e_m) - k) - V(e_m) = H$$

The above result carries over as an increase in k lead to lower utility, thus the bank fails if $k > \overline{k}$ and survives otherwise. Again, $\overline{k}$ is decreasing in H and a is increasing in H. In order to have $\overline{k}$ and a continuous in H, we will assume that $c(0) = 0$.

Next, we will show that three scenarios can arise depending on the participation value H.

i) H is high such that

$$U_1(r(1, e_m)) + U_2(\hat{C}(e_m)) - V(e_m) < H \tag{5}$$

Condition5 represents a case where even when no deposit is withdrawn, participation value is low such that the bank will always fail. Indeed, in this case, it is more likely that there will be no banking at all. Denote this level of H by $\overline{H}$.

[9] $F(\gamma|e) = P(k - \hat{C}|e \leq \gamma|e)$
$= 1 - P(\hat{C}|e \leq k - \gamma|e) = 1 - \Phi(k - \gamma|e)$

ii) H is low such that

$$U_1(r(1, e_m)) + U_2(-c(1 - \hat{C}(e_m))) - V(e_m) \geq H$$

Here, the bank will survive even the highest possible withdrawal demand of one and never fail. Denote this level of H by $\underline{H}$.

iii) The participation value is in the intermediate values such that $\underline{H} < H < \overline{H}$.

In this case, a withdrawal demand of size $k = 1$ or more precisely of the size $k < \overline{k}$ $(1 - k < a)$ will liquidate the bank, otherwise the bank will continue to end period. There are two equilibria, one in which everyone withdraw and the bank fails and the other where no one withdraws leading to a continuation of banking. Note that the game which gives rise to multiple self-fulfilling equilibria is that between bank manager and depositors. A large withdrawal demand will make the bank manager decide to withdraw his effort as the his utility falls below the participation value. However, the opposite can be true. If depositors suspect that the manager will withdraw his effort, maybe because there is likely to be high withdrawal demand, it will ensure that everyone will withdraw and the bank will fail.

3 Economic Fundamentals

Previously, we have assumed that return is dependent only on effort and the size of investment. In this section return is made to depend on the fundamental of the economy or the random state of nature $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$, return function is given by $r(\theta, 1, e)$ continuous and strictly increasing in θ. Note that the fundamental is observed in $t = 1$ after the level of effort is decided. If the distribution of θ is known, similarly to the above analysis, we can suppress θ and summarise its distribution in $Z(r|e)$ with probability density $z(r|e)$. The transformed principle-agent problem is given as follow

$$\max_{c(\gamma), e} \int_{\gamma \in (0, \overline{\gamma}]} [c(\gamma) - \gamma] f(\gamma|e)\, d\gamma \tag{6}$$

$$\text{subject to} \quad \int_{\underline{r}}^{\overline{r}} U_1(r) z(r|e)\, dr + \int_{\gamma \in (0, \overline{\gamma}]} U_2(-c(\gamma)) f(\gamma|e)\, d\gamma - V(e) \geq H \tag{7}$$

$$\int_{\underline{r}}^{\overline{r}} U_1(r) z_e(r|e)\, dr + \int_{\gamma \in (0, \overline{\gamma}]} U_2(-c(\gamma)) f_e(\gamma|e)\, d\gamma = V'(e) \tag{8}$$

and the first order condition

$$\frac{1}{U_2'(-c(\gamma))} = \lambda' + \mu' \frac{f_e(\gamma|e)}{f(\gamma|e)} \tag{9}$$

This is the same as equation4, thus if μ' can be shown to be greater than zero then $c(\gamma)$ must be strictly increasing in γ. The proof for $\mu' > 0$ is similar to the earlier proof for

$\mu > 0$ taking into account that $\int_{\underline{r}}^{\overline{r}} U_1(r) z_e(r|e)\, dr > 0$ if $Z(r|e)$ has a monotonic increasing likelihood-ratio property[10] which we will assume.

3.1 The minimum size dependent on θ

In the previous section, we show that the minimum size requirement is increasing in H. If we consider a given level of participation value H, with similar arguments as previously, we can show that the minimum size requirement depend on the level of fundamental θ, in this case it will be continuous and strictly decreasing in θ, denote by $a(\theta)$. Agian this and the result in the next subsection depend crucially on the condition that $c(\gamma)$ is an increasing function.

3.2 Perfect Information

In addition, analogous to previous result, when the fundamental is perfectly observed, the following is true

i) When θ is low such that

$$U_1(r(\theta, 1, e_m)) + U_2(\hat{C}(e_m)) - V(e_m) < H \tag{10}$$

The bank will always fail. We will call this region of the fundamental, the unstable region $\boldsymbol{\theta}_{us} = \{\theta | \theta < \underline{\underline{\theta}}\}$ where $\underline{\underline{\theta}}$ is θ such that

$$U_1(r(\theta, 1, e_m)) + U_2(\hat{C}(e_m)) - V(e_m) = H \tag{11}$$

ii) When θ is high such that

$$U_1(r(\theta, 1, e_m)) + U_2(-c(1 - \hat{C}(e_m))) - V(e_m) \geq H$$

The bank will always survive. Denote this region of fundamental by the stable region $\boldsymbol{\theta}_s = \{\theta | \theta \leq \overline{\overline{\theta}}\}$ where $\overline{\overline{\theta}}$ is θ such that

$$U_1(r(\theta, 1, e_m)) + U_2(-c(1 - \hat{C}(e_m))) - V(e_m) = H$$

iii) When the fundamental value falls between the unstable and the stable regions. There are two self-fulfilling multiple equilibria, one with a bank run and the other with a bank survival. Denote this region of fundamental as the intermediate region $\boldsymbol{\theta}_m = \{\theta | \underline{\underline{\theta}} < \theta \leq \overline{\overline{\theta}}\}$.

Also, note that there exist three non-empty regions of the fundamental, $\boldsymbol{\theta}_{us}$, $\boldsymbol{\theta}_m$ and $\boldsymbol{\theta}_s$, only if $0 < a(\overline{\overline{\theta}}) < a(\underline{\underline{\theta}}) < 1$. The following remark summarises this result.

Remark 1 In this game, a depositor chooses an action from $\{withdraw,\ not\ withdraw\}$. A profile of actions is a Nash equilibrium if no individual depositor has an incentive to deviate. For each $\theta \in \boldsymbol{\theta}_{us}$(resp., for each $\theta \in \boldsymbol{\theta}_s$) there is a unique pure strategy Nash

[10] If the density$z(r|e)$has a strict monotone likelihood then $\frac{z(r|e_2)}{z(r|e_1)}$ is increasing in r for $e_1 < e_2$ which implies that $\int_{\underline{r}}^{\overline{r}} U_1(r) z(r|e_2)\, dr > \int_{\underline{r}}^{\overline{r}} U_1(r) z(r|e_1)\, dr$ when $U_1(r)$ is increasing in r. Therefore $\int_{\underline{r}}^{\overline{r}} U_1(r) z(r|e)\, dr$ is increasing in e. Thus $\frac{d}{de} \int_{\underline{r}}^{\overline{r}} U_1(r) z(r|e)\, dr = \int_{\underline{r}}^{\overline{r}} U_1(r) z_e(r|e)\, dr > 0$.

equilibrium where all depositors choose to withdraw (resp. choose not to withdraw) while for each $\theta \in \boldsymbol{\theta}_m$, there are two pure strategy Nash equilibria, one where all depositors choose $\{not\ withdraw\}$and another where all depositors choose $\{withdraw\}$.

This remark justifies our interpretation of $\boldsymbol{\theta}_{us}$ as the unstable region where the bank always collapses and $\boldsymbol{\theta}_s$ as the stable region where the bank always survives. $\boldsymbol{\theta}_m$ is the middle region where the there are two equilibrium outcomes: one where the bank always survives and another where the bank always fails. This is the region with self-fulfilling multiple equilibria: the first equilibrium is the one where the bank always survives and the second equilibrium is the one where there is a bank run and represents a coordination failure. As we shall show, whether or not these three regions are non-empty is the key to characterizing equilibria with noisy signals on the fundamentals.

4 Noisy signals

When the assumption of common knowledge is relaxed and depositors no longer observe the fundamental θ, at $t = 1$ but instead receive a noisy signal about it. If the fundamentals can be partitioned into three non-empty subset as above then as in Morris and Shin (1998) the equilibrium outcome is unique. However, we will later show that with a problem of moral hazard and thus increasing cost of borrowing, some economy, especially those of emerging markets and less developed financial systems can be faced with severe cost of credits or a limit on borrowing which raise the minimum size requirement to above zero leading to an empty stable region. In this case, there again arises multiple equilibria with self-fulfilling expectation.

The timing of events is exactly as before except that now at $t = 1$, depositors cannot observe θ but instead observe a signal y which is drawn independently and uniformly from $Y(\theta) \subset \left[\underline{\theta}, \overline{\theta}\right]$, where $Y(\theta) = [\theta - \varepsilon, \theta + \varepsilon]$ if $\theta \in [\underline{\theta} + \varepsilon, \overline{\theta} - \varepsilon]$, where $\varepsilon > 0$ is the term representing noise in the fundamentals; $Y(\theta) = [\theta, \theta + \varepsilon]$ if $\theta \in [\underline{\theta}, \underline{\theta} + \varepsilon)$; $Y(\theta) = [\theta - \varepsilon, \theta]$ if $\theta \in (\overline{\theta} - \varepsilon, \overline{\theta}]$[11]. A strategy for a depositor at $t = 1$ is a function from what he observes to his set of actions which has two components $\{withdraw,\ not\ withdraw\}$. A profile of strategies is a Bayesian equilibrium if no individual depositor has an incentive to deviate. Consider the strategy profile where every depositor withdraws if and only if observed signal y is less than $\bar{y}$. Such a strategy profile is called a strategy profile with a switching point $\bar{y}$,denote by $I_{\overline{y}}$[12].

Remark 2 When $a(\theta)$ is continuous and strictly decreasing in θ, $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$. If $\boldsymbol{\theta}_{us}$, $\boldsymbol{\theta}_m$ and $\boldsymbol{\theta}_s$ are all non-empty, then for a suitable choice of $\varepsilon > 0$ there exists a unique Bayesian equilibrium in strategies with a switching point y^*. In particular, there exists a unique value of θ, denoted by θ^*, such that the bank fails if $\theta < \theta^*$ and survives if $\theta > \theta^*$.

Proof. The result of Morris and Shin (1998) follow through if we can show that depositors' expected utility at the switching point $\overline{y}$, $u(\overline{y}, I_{\overline{y}}) = \frac{1}{2\varepsilon} \int_{[\overline{y}-\varepsilon,\overline{y}+\varepsilon]\cap\left\{\theta|s(\theta,I_{\overline{y}})\geq a(\theta)\right\}} R_2 d\theta$ is

[11] This signalling structure is the same as in Morris and Shin (1998). We use this signalling structure to maintain comparability with their results.

[12] Note that $\overline{y} \in (\underline{\underline{\theta}} - \varepsilon, \overline{\overline{\theta}} + \varepsilon)$, otherwise depositors know for sure that $\theta \in \theta_{us}$ or $\theta \in \theta_s$ and such a strategy cannot be optimal.

strictly increasing in $\overline{y}$ where $s(\theta, I_{\overline{y}}) = \frac{1}{2\varepsilon}\int_{\theta-\varepsilon}^{\theta+\varepsilon} I_{\overline{y}}dy$ is the realised proportion of deposits not withdrawn given $I_{\overline{y}}$. See appendix B. ■

This remark shows that when the space of fundamentals can be partitioned into three non-empty subsets, the first region in which the bank always fails, a second region in which there is multiple equilibria and a third region in which the bank always survives, the unique equilibrium result of Morris and Shin (1998) applies to our model as well. When all three regions are non-empty, a small noise in the observation of the true value of the fundamentals, implies that it can never be common knowledge that fundamentals are in $\boldsymbol{\theta}_m$. Morris and Shin's proof then goes through in our case with a suitable relabelling of variables.

In contrast, the next proposition provides a set of conditions under which multiple equilibria persist even with noisy signals on fundamentals.

Proposition 1 Suppose it is common knowledge that $\boldsymbol{\theta}_m = \left[\underline{\theta}, \overline{\theta}\right]$ while $\boldsymbol{\theta}_{us}$ and $\boldsymbol{\theta}_s$ are empty. Then, multiple equilibria exist and in particular self-fulfilling bank runs exist.

Proof. If it is common knowledge that $\boldsymbol{\theta}_s$ and $\boldsymbol{\theta}_{us}$ are empty, for $\theta \in [\underline{\theta}+\varepsilon, \overline{\theta}-\varepsilon]$, where $\varepsilon > 0$, at each $y \in [\theta-\varepsilon, \theta+\varepsilon]$, it remains common knowledge that $\theta \in \boldsymbol{\theta}_m$. The same remains true when $\theta \in [\underline{\theta}, \underline{\theta}+\varepsilon)$ and $\theta \in (\overline{\theta}-\varepsilon, \overline{\theta}]$. Therefore, conditional on θ, at every signal $y \in Y(\theta)$, it is common knowledge that $\theta \in \boldsymbol{\theta}_m$. Therefore, the strategy profile where each depositor chooses $\{not\ withdraw\}$ at each y is an equilibrium. Further, the strategy profile where each depositor chooses $\{withdraw\}$ at each y is an equilibrium. ■

Proposition 1 serves as a benchmark case because it specifies the key common knowledge restrictions for the existence of multiple equilibrium outcomes. In the benchmark case, the assumption is that $\boldsymbol{\theta}_{us}$, the region where the bank always fails and $\boldsymbol{\theta}_s$, region where the bank always survives, are both empty. Under this assumption, even with noisy signals on fundamentals, it remains common knowledge that the fundamentals are in $\boldsymbol{\theta}_m$. From this it follows that both bank runs and bank survival continue to remain equilibrium outcomes. For $\boldsymbol{\theta}_{us}$ to be empty we need to have $U_1(r(\theta, 1, e_m)) + U_2(\hat{C}(e_m)) - V(e_m) \geq H$. This is restrictive as it assumes that investment projects always guarantee a high enough return at $t = 2$. On the other hand, we feel that the assumption of empty $\boldsymbol{\theta}_s$ is more plausible especially when the bank operates in an economy where the financial markets are not fully developed because a non-empty $\boldsymbol{\theta}_s$ implies that if everyone withdraw, the bank will still survive until the end period.

5 Emerging Markets

Next, we argue that, with the problem of moral hazard, banks can be faced with severe rationing or high cost of borrowing and decide to collapse regardless of fundamentals θ. This may be true for banks in emerging market economies with weak financial system and moral hazard problem. In such economies, $\boldsymbol{\theta}_s$ is empty.

We examine the optimal decision of the bank under these scenarios and give a brief intuition about the effect of the costs of liquidation.

5.1 Credit rationing

Here we show that when there is severe credit rationing in market for bank loans, the stable region $\boldsymbol{\theta}_s$ is empty. In fact, credit rationing is observed in most financial markets and in particular, in the market for bank loans (see for instance, Guttentag and Herring (1987)). We can rationalize credit rationing in our set-up by observing that the market may not be able distinguish between banks that borrow to ward off a liquidity threat and banks that borrow because they are insolvent. Imagine two banks with apparently sound fundamentals. One bank is solvent with severe liquidity problem. The other with moral hazard problem where the bank's management is at fault. As this is not observable by the outside parties, it will not be reflected in the observed fundamentals. Thus it is reasonable to assume that the third party acting as a lender of last resort may have a strong reservation about lending to either bank as it can not, given a time limit, distinguishes between the two. Potential lenders faced with uncertainty may ration the borrower as well as raising the rate to cover a greater potential for loss especially, when as in our case, the solvency of potential borrowers is not observed. Here we show a condition that imposes a limit on the amount that bank can borrow above which the cost of borrowing will be infinite. Let α_θ be the value of $1-k$ such that

$$U(r(\theta,1,e_m)) + U_2(-c(k-\hat{C}(e_m))) - V(e_m) = H, \forall\theta.$$

Denote the limit on borrowing by $\overline{\gamma}$ and let $\gamma(\alpha) = 1-\alpha_\theta-\hat{C}(e_m)$. We shall assume that rationing by the markets is severe i.e. $\gamma(0) = 1-\hat{C}(e_m) > \overline{\gamma}$. Let $\overline{\alpha}_\theta$ be the value of α such that $\gamma(\alpha) = \overline{\gamma}$. Note that for any given θ, if $\alpha < \overline{\alpha}_\theta$ the bank will collapse. Remark also that $\overline{\alpha}_{\overline{\theta}} > 0$. In addition, because the minimum size α_θ is strictly decreasing in θ. Therefore, $\forall\theta$, there exists $\overline{\alpha} > 0$ such that $\overline{\alpha} \leq \overline{\alpha}_\theta$. This implies that there exists $\alpha < \overline{\alpha}$ such that the bank will collapse regardless of $\theta \Rightarrow \boldsymbol{\theta}_s$ is empty.

5.2 The cost of borrowing

Apart from the fact that banks may have limited access to credits, troubled banks, especially when its solvency is not observed, may also be subjected to high rate of interest for loans. Also the costs of borrowing does not only reflect the loan rates but among other things, the transaction cost and more importantly the cost to its reputation. In order to borrow it will have to convince the market that it is solvent. This, in itself, will damage its reputation as being a worthy borrower and therefore, affect the terms on which it will be able to borrow in any future crisis[13].

Consider the case when all depositors wish to withdraw, $k = 1$ $(\alpha = 0)$, and assume that the cost of borrowing is high such that

$$U_1(r(\theta,1,e_m)) + U_2(-c(1-\hat{C}(e_m))) - V(e_m) < H, \forall\theta.$$

Therefore when $\alpha = 0$ and $\gamma = 1-\hat{C}(e_m)$ the bank will always choose to collapse. By continuity of $c(\gamma)$ in α, there exist $\underline{\alpha}_\theta$ close to 0 such that

$$U_1(r(\theta,1,e_m)) + U_2(-c(1-\alpha-\hat{C}(e_m))) - V(e_m) < H, \forall\alpha < \underline{\alpha}_\theta.$$

Therefore, $\forall\theta$, there exists $\underline{\alpha} > 0$ such that $\underline{\alpha} \leq \underline{\alpha}_\theta$. This implies that there exists $\alpha < \underline{\alpha}$ such that the bank will collapse regardless of $\theta \Rightarrow \boldsymbol{\theta}_s$ is empty.

In contrast to proposition 1, the assumption of empty stable region is more plausible than that needed in proposition 1. We show that even with this weaker assumption, multiple equilibria exist.

[13] As Bagehot (1873) noted 'Every banker knows that if he has to prove that he is worthy of credit, however good maybe his argument, in fact his credit is gone...'. (quoted in Guttentag and Herring (1987)).

Before we state the next proposition, we need the following definitions (see also Morris and Shin (1998)). Let $\pi(y)$ be the aggregate proportion of deposits not withdrawn in period 1 when the value of signal is y. Let $s(\theta, \pi)$ be the realized proportion of deposits not withdrawn in period 1 when the state of the fundamentals is θ, given π. Under our assumptions, when $\theta \in [\underline{\theta} + \varepsilon, \overline{\theta} - \varepsilon]$,

$$s(\theta, \pi) = \frac{1}{2\varepsilon} \int_{\theta-\varepsilon}^{\theta+\varepsilon} \pi(y) dy$$

Further, for $\theta \in [\underline{\theta} + \varepsilon, \overline{\theta} - \varepsilon]$, let $u(y, \pi)$ be the expected payoff of $\{not\ withdraw\}$, given signal y and π. Again, for a given level of effort and figure 1 hidden. We have

$$\begin{aligned} u(y, \pi) &= \frac{1}{2\varepsilon} \int_{[y-\varepsilon, y+\varepsilon] \cap \{\theta | s(\theta,\pi) \geq a(\theta)\}} R_2 d\theta, \\ &= 0 \ otherwise \end{aligned}$$

Note that when θ is close to $\underline{\theta}$ or $\overline{\theta}$, in particular, when $\theta \in [\underline{\theta}, \underline{\theta} + \varepsilon)$ and $\theta \in (\overline{\theta} - \varepsilon, \overline{\theta}]$, the limits of the integrations must be adjusted.

Denote a strategy profile with a switching point $\bar{y}$ by $I_{\overline{y}}$ and let $u(\overline{y}, I_{\overline{y}})$ denotes the corresponding payoff.

Proposition 2 If $a(\theta)$ is continuous and strictly decreasing in θ, $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$. Suppose it is common knowledge that $\theta \in \theta_m \cup \theta_{us}$ while θ_s is empty, then multiple equilibria exist and in particular self-fulfilling bank runs exist.

Proof. As it is common knowledge that $\boldsymbol{\theta}_s$ is empty, then at every signal y, it is common knowledge that $\theta \in \boldsymbol{\theta}_m \cup \boldsymbol{\theta}_{us}$. Therefore a strategy profile in which every depositor choose $\{withdraw\}$ regardless of the signal value y is an equilibrium. It remains to show that there exists $\theta^* \in \left[\underline{\theta}, \overline{\theta}\right]$ such that for all $\theta \in (\theta^*, \overline{\theta}]$, in addition, $\{not\ withdraw\}$ is also an equilibrium outcome. First note that if $\pi(y) \geq \pi'(y)$ for all y, then $u(y, \pi) \geq u(y, \pi')$ for all y and $u(\overline{y}, I_{\overline{y}})$ is continuous and strictly increasing in $\overline{y}$.This follows by arguments analogous to lemma 1 and lemma 2 in Morris and Shin (1998). Further, observe that for a suitable choice of ε, we have $Y(\underline{\theta}) \subset \boldsymbol{\theta}_{us}$ while $Y(\bar{\theta}) \subset \boldsymbol{\theta}_m$. Now, a depositor with a signal $y \in Y(\underline{\theta})$ knows that $\theta \in \boldsymbol{\theta}_{us}$. Therefore, we have $u(\bar{y}, I_{\overline{y}}) < 1$ if $\bar{y} \in Y(\underline{\theta})$. Next, a depositor with a signal $y \in Y(\bar{\theta})$, knows that $\theta \in \boldsymbol{\theta}_m$. For each $\theta \in \boldsymbol{\theta}_m$, each depositor will choose $\{not\ withdraw\}$ if he expects that all other depositors will choose $\{not\ withdraw\}$. Therefore, if every depositor expects every other depositor to choose $\{not\ withdraw\}$, as there is a continuum of depositors, for an individual depositor with a signal $\bar{y} \in Y(\bar{\theta})$, $u(\bar{y}, I_{\overline{y}}) > 1$. Therefore, there exists a unique signal $y^* \in \left[\underline{\theta}, \overline{\theta}\right]$ such that $u(y^*, I_{y^*}) = 1$. Also, $y^* \notin Y(\underline{\theta})$ and $y^* \notin Y(\bar{\theta})$. In words, a depositor with signal y will choose $\{withdraw\}$ if $y \leq y^*$ and $\{not\ withdraw\}$ if $y > y^*$. Now, when the equilibrium strategy is I_{y^*}, $s(\theta, I_{y^*})$ is strictly increasing in $\theta \in (y^* - \varepsilon,\ y^* + \varepsilon)$. Further, when $\theta \in (y^* - \varepsilon,\ y^* + \varepsilon)$, $0 < s(\theta, I_{y^*}) < 1$ and at $\theta = y^* - \varepsilon$, $s(\theta, I_{y^*}) = 0$ while at $\theta = y^* + \varepsilon$, $s(\theta, I_{y^*}) = 1$. Further, for a suitable choice of ε, when $\theta + 2\varepsilon \in \boldsymbol{\theta}_{us}$, $s(\theta, I_{y^*})$ is equal to zero. In addition, $s(\theta, I_{y^*})$ is continuous in θ and by assumption, $a(\theta)$ is continuous and strictly decreasing in θ. Therefore, there is a unique value of θ such that $s(\theta, I_{y^*}) = a(\theta)$. Denote this by θ^*. Therefore, when $\theta < \theta^*$, the bank always collapses and when $\theta \geq \theta^*$, the bank can either fail or survives. ■

6 Comparisons to other models of banking

6.1 Liquidity shocks and minimum size

In this section, we argue that typically a certain proportion of the bank's assets are always illiquid and this feature makes banks inherently vulnerable to bank runs, thus ensuring that θ_s is empty. We reinterpret fundamentals of banking as liquidity shocks and show that the model of banking presented in section 2 can be derived as a reduced form of the single bank model of Diamond and Dybvig (1983) (hereafter D-D) where the proportion of the bank's assets that are illiquid is derived endogenously.

In (D-D), bank can achieve optimal risk sharing to its customers by offering demand deposit contract which transform illiquid assets into liquid liabilities. There are three time periods, $t = 0, 1, 2$ and two type of agents, tppe 1 and type 2 with a utility function of the form

$$\begin{aligned} U(c_1, c_2; \Theta) &= u(c_1) && \text{if } j \text{ is of type 1 in state } \Theta \\ &= \rho u(c_1 + c_2) && \text{if } j \text{ is of type 2 in state } \Theta \end{aligned}$$

where Θ represents the state private information, c_1 and c_2 denote consumption in period $t = 1$ and $t = 2$. At $t = 0$ all agents are identical and choose to deposit with the bank. At $t = 1$ agents privately learn their type and can choose to withdraw. At $t = 2$ returns on production are realised and divided between the remaining depositors. In addition, both D-D and our models assume long term production technology with a cost of early liquidation. Demand deposit contract however offers liquid liabilities with a fixed interest rate r_1 at $t = 1$,(r_1 is greater than the value of early liquidation of assets). In D-D when r_1 is derived from optimal risk sharing, r_1 is strictly decreasing in the proportion of type 1 depositors, $T \in (0, 1)$ when it is known ex ante. The return on investments at $t = 2$, r_2 depends on r_1, the fraction of deposits withdrawn at $t = 1$; f, and a fixed return from long term production at $t = 2$, L. $r_2 = L(1 - r_1 f)/(1 - f)$.

T can be interpreted as representing the state of nature θ where $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$, $\underline{\theta} > 0, \overline{\theta} < 1$, r_1 decreasing in θ and r_2 increasing in θ, $r_1 < r_2$. In our model, they are assumed to be fixed. However, we can incorporate a feature of the D-D R_1 and R_2 will be decreasing and increasing in θ respectively. Note also that proposition1 and proposition2 apply with decreasing R_1 and increasing R_2.

In D-D, it shown (pages 410-411) that there exists an upper bound of the fraction of deposits withdrawn at $t = 1$ that allows banking to continue to $t = 2$. If the realised fraction of deposits withdrawn at $t = 1$, w, is equal to this upper bound, denoted by $\overline{w} = (L - r_1)/r_1(L - 1)$, the rates of returns for both periods will be the optimally chosen interest rate at $t = 1$, r_1. If it is greater the bank will fail because all type 2 depositors will rush to withdraw their deposits. Since the minimum size requirement is the lowest possible proportion of deposits remaining in period 2 that permits the ongoing of production, the minimum size $a(\theta)$ is equal to $1 - \overline{w}$. The upper bound $\overline{w}$ is a function of r_1 and it is increasing in θ, the fraction of type 1 deposits. Thus $a(\theta)$ is decreasing in θ and $a(\theta) > 0$ if $\theta \in (0, 1)$. Therefore $\boldsymbol{\theta}_s$ is empty. Note that using the formula described in D-D, $\theta > 0$, implies that $a(\theta) < 1$. Thus it is in fact common knowledge that $\boldsymbol{\theta}_{us}$ is empty as well provided that $r_2 > r_1$.

Given the specifications of D-D, we have shown that the following properties are true: $\boldsymbol{\theta}_{us}$ and $\boldsymbol{\theta}_s$are empty and for any $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$, $\underline{\theta} > 0, \overline{\theta} < 1$. Therefore, it is common knowledge that $\theta \in \boldsymbol{\theta}_m$ even when there is noisy observation of fundamentals. It follows that multiple equilibria always exist.

We rule out "narrow banks" which requires that demand deposits be backed entirely by safe short-term assets as this implies that socially optimal risk-sharing will not be implemented. Our main result suggests that there is a discontinuity in the transition from "narrow banks" to banks with a "small" maturity mismatch and a minimum size requirement due to a non-convex banking technology. In this case, multiple equilibria persist.

6.2 Risk sharing

Here we present a slight variation of our model taken from Goldstein and Pauzner (2000). The model is based on D-D, there are three time periods $t = 0, 1, 2$, one good and a continuum $[0, 1]$ of agents. Each agent is born at $t = 0$ with an endowment of 1. With probability λ an agent is impatient and with probability $1 - \lambda$ she is patient. Each agent learns their type at $t = 1$ which is a private knowledge known only to them.

There exists a single bank who have access to the same production technology; one unit of investment input at $t = 0$ yields either 1 unit of output at $t = 1$ or $L(\theta)$ increasing in θ at $t = 2$. If the bank has enough resources to pay for all the early withdrawal, $n < 1/r_1$, each agent receive a fixed return of $r_1 > 1$ for each unit of investment withdrawn at $t = 1$ or a return of $r_2 = L(\theta)(1 - nr_1)/1 - n$ for each unit withdrawn at $t = 2$ where n is the proportion of individuals demanding early withdrawal. However, if $n \geq 1/r_1$, the bank fails and liquidates all its investment, the proceeds of which are divided among the agents who demand early withdrawal.

In this model as in our model, demand deposit contract offers a fixed return of r_1 greater than 1, the yield given by the production technology at $t = 1$. It is this higher return of r_1 which gives us a minimum size requirement which equals $1 - 1/r_1$.Since r_1 is a fixed return greater than one, $1 - 1/r_1$ is a constant greater than 0. In order to ensure the existence of the unstable region, it is assumed that there exists a non-empty set of θ such that $L(\theta) < 1$. The existence of a stable region is however somewhat troublesome. As the minimum size requirement is a positive constant regardless of the fundamental θ. If at any value of θ all agents decide to demand early withdrawals, the bank will fail regardless of how high the fundamental value is. In Goldstein and Pauzner (2000), to ensure the existence of the stable region, they assume the availability of external finance when the bank is faced with a crisis. Here this means that the external lender of last resort must be able to provide the finance greater than that of $1 - 1/r_1$ of the overall deposit. Another way of ensuring the existence of the stable region is to deviate slightly from the model and assume that when the fundamental is extremely high, the technology yields a return larger than 1 even at $t = 1$[14]. In other word, this assumption ensures the availability of the bank's internal finance. However, as earlier argued, both the external and internal finance may not be available to emerging market economies with weak financial systems because moral hazard problem can lead to severe credit rationing and high cost of borrowing.

As in D-D, the bank through their demand deposit contract provides risk sharing between patient and impatient individuals by transforming illiquid assets to liquid liabilities. We argue that with this function comes a possibility of a bank run. As long as the bank continues to offer the demand deposit contract and the possibility of external lender or internal finance

[14] As long as this return is less than r_1, the bank will still fail if all agents decide to withdraw at $t = 1$. With optimal contract such as that of D-D, this will be less than r_1.

is never certain, this model as a special case of our earlier model can be applied to the result of proposition 2.

7 Empirical and policy issues

In our model of banking, a crisis will occur if the fundamentals are weak enough i.e. when $\theta \in [\underline{\theta}, \theta^*]$. It can also occur as a result of a shift of expectation even when the fundamentals are sound i.e. $\theta \in (\theta^*, \bar{\theta}]$. Therefore, our model is able to explain both fundamental based bank runs and panic runs. Indeed for a certain range of fundamentals, multiple equilibria exist even with noisy signals about the fundamentals. This has applications to the study of specific episodes of financial collapse and currency crisis such as the recent Asian financial crisis or the earlier Mexican Peso crisis in 1994. In our model of banking,

As pointed out by Thomas (1999), one implication of Morris and Shin (1998) (see also Morris and Shin (1999a)), is that the onset of a crisis should be anticipated as the fundamentals evolve to approach the critical value needed to trigger a speculative attack On the other hand, our main result, that there is a region of fundamentals with multiple equilibrium outcomes, implies that a financial crisis can be largely unanticipated by markets. In fact, Edwards (1986), using international data on the pricing of bank loans to developing countries, finds that international financial markets had only partially anticipated the debt crisis of 1982[15].

Furthermore, the severity and contagion effects of the crisis is certainly unaccounted for purely by economic fundamentals. Several recent papers on the Asian financial crisis collected in Agenor et al (1999))[16] argue that the phenomenon of contagion, where a crisis in one economy triggers off a crisis in another institutionally similar economy, can be usefully studied using models of multiple equilibria. Masson (1997) concludes that there is a role for pure contagion which is not linked to macroeconomic fundamentals and can only occur in a situation in which multiple equilibria were possible.

The implications of our model for policies to prevent banking crises are similar to that of other multiple equilibria models of banking. Chang and Velasco (1998) apply the Diamond and Dybvig (1983) model of banking to the study of the Asian financial crisis to show that, with fixed exchange rates, domestic self-fulfilling bank crisis translates into a run on that country's currency (see Sachs, Tornell and Velasco (1996) for a related attempt to explain the Mexico Peso crisis).Our analysis also suggests that the problem of maturity mismatches can have a negative impact when capital markets are liberalized in emerging economies. The problem of maturity mismatches can be aggravated by financial liberalization and capital flows from abroad. Indeed, the nature of demand deposit contracts and of banks assets coupled with potentially large changes in financial flows ensure that a surprised run resulting from refusals to roll over debt can always occur. Rogoff (1999), citing Diamond and Dybvig (1983), makes a similar point. Fischer (1999) takes this argument further to make a case for

[15] Several empirical studies of other episodes of financial and currency crisis make a similar claim. Examples include Rose and Svensson (1994) on the crisis in currencies in the European exchange rate mechanism, Jeanne (1997) (see also Jeanne and Masson (2000)) on the experience of the French franc from 1987-1994, Flood and Marion (2000) on the crisis in the Mexican Peso in 1994.

[16] In particular see chapters 1, 2, 8, 9 and 10 in Agenor et al (1999). For a dissenting view, however, see the chapter by Morris and Shin (1999a) in the same volume where they study the onset of currency attacks by looking at a dynamic extension of their 1998 paper in which the fundamentals of the economy evolve stochastically over time.

an international lender of last resort.

Our model suggests two type of policy interventions, one that facilitate the ability of agents to coordinate on the right equilibrium and the other which lowers the critical value of fundamentals. that policy interventions that facilitate the ability of agents to coordinate on the right equilibrium will prevent bank runs and other forms of financial crisis. Deposit insurance and suspension of convertibility (standstills) may prevent runs which are due to self-fulfilling expectation. However, these policy interventions that facilitate coordination on the right equilibrium do not make sense in models with a unique equilibrium since bank runs are driven by fundamentals. In addition, there is a concern that such policies may cause severe moral hazard problem and encourage large capital inflows which in turn aggravate the problem. Financial liberalisation thus should be implemented with care and proper punishment strategies and appropriate monitoring of bank should be in place to eliminate the risk of moral hazard.

Another contrast is in the analysis of the role of transparency in preventing a financial crisis. In our analysis, public announcements that restore transparency coupled with policy interventions that facilitate coordination,may prevent bank runs when $\theta \in [\underline{\theta}, \theta^*]$. However, this is may not always be true in models of bank runs with a unique equilibrium. Chan and Chui (2000) in their paper which provide an extension of Morris and Shin (1998) find that in some cases currency attacks are prevented by non-transparency. Thus the role of transparency in unique equilibrium models are somewhat unclear.

Some other forms of policy intervention can help reduce the probability of a crisis. Increasing the return in the end period and decreasing the minimum size requirement for all level of the fundamentals will lower the critical value, make smaller the region where successful attacks are certain and thus reducing the probability of bank runs for some non-empty subset of fundamentals. Promoting an environment for business ventures and increasing effort of bank manager can lead to increase in the returns on investment and lower the critical value. Raising manager's effort will also increase the cash reserve and indirectly lower the minimum size requirement provided that disutility from higher cost of effort is not too large. This may suggest some benefits from a policy scheme which rewards manager for higher effort and impose a penalty otherwise. As effort is not verifiable, the level of reserve and investment return will have to used as a guidance. A badly performed bank can be subject to future investigation as a penalty and a deterrent for low effort.

8 Conclusion

We show that even with noisy signals on fundamentals, multiple equilibria due to a coordination failure exist in models of banking with moral hazard problem. We argue that the conditions under which this happens can arise in a markets with weak financial system. In such a market, the cost of borrowing not only increases with the amount of borrowing but can be too high such that the bank manager will decide to liquidate the bank. This high cost reflects both the financial aspect of the bank and also any terms and conditions that maybe imposed upon its management. In addition, there can exist a limit on borrowing such that the bank will collapse when all of its depositors decide to withdraw.

9 Appendix

Appendix A

Taking expectation of 4, the fact that $Ef_e/f = 0$ gives

$$\int_{\gamma\in(0,\overline{\gamma}]} \frac{1}{U_2'(-c(\gamma))} f(\gamma|e)\, d\gamma = \lambda$$

From 4, substituting $f_e(\gamma|e) = [\frac{1}{U_2'(-c(\gamma))} - \lambda]\frac{f(\gamma|e)}{\mu}$ into 3 and using the above, we have

$$\begin{aligned}
\mu V'(e) &= r_e(1,e)\, U_1'(r(1,e)) + \int U(-c)\frac{1}{U'(-c)} f_e(\gamma|e)\, d\gamma \\
&\quad - \int U(-c)\, f(\gamma|e)\, d\gamma \int \frac{1}{U'(-c)} f(\gamma|e)\, d\gamma \\
\mu V'(e) &= r_e(1,e)\, U_1'(r(1,e)) + Cov(U(-c), \frac{1}{U'(-c)})
\end{aligned}$$

By assumption, $r_e(1,e)\, U_1'(r(1,e)) > 0$ and $V'(e) > 0$. Since the covariance of $U(-c)$ and $1/U'(-c)$ is nonnegative as they are both increasing functions , μ must be nonnegative. μ cannot be zero as this will give a constant $c(\gamma)$ and generally violates 3.

Appendix B

$$\begin{aligned}
s(\theta, I_{\overline{y}}) &= 0 && \text{when } \theta < \overline{y} - \varepsilon \\
&= \frac{1}{2\varepsilon}[\theta + \varepsilon - \overline{y}] && \text{when } \overline{y} - \varepsilon \le \theta \le \overline{y} + \varepsilon \\
&= 1 && \text{when } \theta > \overline{y} + \varepsilon
\end{aligned}$$

and

$$u(\overline{y}, I_{\overline{y}}) = \frac{1}{2\varepsilon}\int_{\max\{\overline{y}-\varepsilon, \hat{\theta}\}}^{\overline{y}+\varepsilon} R_2 d\theta.$$

where $\hat{\theta}$ is θ such that $s(\theta, I_{\overline{y}}) = a(\theta)$. However, at $\overline{y}$ depositors must be indifferent between $\{withdraw\}$ and $\{not\ withdraw\}$, we must have $u(\overline{y}, I_{\overline{y}}) = R_1 < R_2$. If $\max\{\overline{y}-\varepsilon, \hat{\theta}\} = \overline{y}-\varepsilon$ then, $u(\overline{y}, I_{\overline{y}}) = R_2 > R_1$,contradiction. Therefore

$$u(\overline{y}, I_{\overline{y}}) = \frac{1}{2\varepsilon}\int_{\hat{\theta}}^{\overline{y}+\varepsilon} R_2 d\theta. = \frac{1}{2\varepsilon}[\overline{y} + \varepsilon - \hat{\theta}]R_2$$

If $s(\hat{\theta}, I_{\overline{y}}) = a(\hat{\theta}) = 1$, $\hat{\theta} < \underline{\underline{\theta}}$ and there exists a nonempty subset of $\theta \in \boldsymbol{\theta}_{us}$ such that the bank survives but this cannot be true as the bank always fails in the unstable region, we must have $\hat{\theta} > \underline{\underline{\theta}}$. Similarly, $\hat{\theta} < \overline{\overline{\theta}}$. Recall that $0 < a(\overline{\overline{\theta}}) < a(\underline{\underline{\theta}}) < 1$, thus $s(\hat{\theta}, I_{\overline{y}}) = \frac{1}{2\varepsilon}[\hat{\theta}+\varepsilon-\overline{y}] = a(\hat{\theta})$. In other words, we must have $s(\hat{\theta}, I_{\overline{y}}) - a(\hat{\theta}) = 0$. $\frac{d}{d\overline{y}}[s(\hat{\theta}, I_{\overline{y}}) - a(\hat{\theta})] = -\frac{1}{2\varepsilon}$. $\frac{d}{d\hat{\theta}}[s(\hat{\theta}, I_{\overline{y}}) - a(\hat{\theta})] = \frac{1}{2\varepsilon} - a'(\theta) > \frac{1}{2\varepsilon}$. In order to satisfy $s(\hat{\theta}, I_{\overline{y}}) - a(\hat{\theta}) = 0$, an increase in $\overline{y}$ will lead to a smaller increase in $\hat{\theta}$. Therefore $u(\overline{y}, I_{\overline{y}}) = \frac{1}{2\varepsilon}[\overline{y} + \varepsilon - \hat{\theta}]R_2$ is strictly increasing in $\overline{y}$.

References

1] Agenor, P-R., M. Miller., D. Vines and A. Weber (edited) (1999): "The Asian Financial Crisis", Cambridge University Press, Cambridge-New York, 1999.

2] Atkeson, A. (2000): "Discussion of Stephen Morris and Hyun Song Shin's Rethinking multiple equilibria in macroeconomic modeling", NBER Macroeconomic Annual 2000.

3] Bagehot, W. (1873): "Lombard Street", Reissued London, Kegan Paul, Trench, Trunber & Co., 1901.

4] Carlsson, H and E. van Damme (1993), "Global Game and Equilibrium Selection", Econometrica, 61, pp 989-1018.

5] Chan, K. and S. Chiu (2000): "The Role of (Non)transparency in a Currency Crisis", mimeo, McMaster University.

6] Chang, R. and A. Velasco (1998): "Financial Crises in Emerging Markets: A Canonical Model", National Bureau of Economic Research Working Paper No.6606.

7] Corsetti, G., S. Morris and H. S. Shin (1999): "Does one Soros make a difference? The role of a large trader in currency crisis", mimeo.

8] Diamond, D. and P. Dybvig (1983): "Bank Runs, Deposit Insurance, and Liquidity", Journal of Political Economy, 91, pp. 401-19.

9] Diamond, D. (1984): "Financial Intermediation and Delegated Monitoring", Review of Economic Studies, 51, pp.393-414.

10] Diamond, D. and R. Rajan "A theory of bank capital", mimeo, University of Chicago.

11] Edwards, S. (1986): "The Pricing of Bonds and Bank loans in International Markets", European Economic Review, 30, pp.565-89.

12] Flood, R. P. and N. P. Marion (2000): "Self-fulfilling Risk Predictions: an application to speculative attacks", Journal of International Economics, 50, pp. 245-68.

13] Fischer, S. (1999): "On the need for an International Lender of Last Resort", mimeo.

14] Freixas, X and J.C. Rochet (1998): "Microeconomics of Banking", MIT Press: Cambridge-London.

15] Goldstein and Pauzner (2000): "Demand Deposit Contracts and the Probability of Bank Runs", mimeo, University of Tel Aviv.

16] Goodhart, C A.E. (1987): "Why do banks need a central bank", Oxford Economic Papers, 39, pp. 75-89.

17] Guttentag, J. and R Herring (1987): "Emergency liquidity assistance for international banks", in Threats to international financial stability, edited by R.Portes and A. K. Swoboda (1987), Cambridge University Press, pp150-195.

18] Holmstorm, B. (1979): Moral Hazard and Observability", Bell Journal of Economics, 10, pp. 74-91.

19] Jeanne, O (1997): "Are currency crisis self-fulfilling?", Journal of International Economics, 43, pp. 263-86.

20] Jeanne, O and P. Masson (2000): "Currency crisis, sunspots, and Markov-switching regimes", Journal of International Economics, 50, pp. 327-50.

21] Jewitt, I. (1988): "Justifying the First-Order Approach to Principal-Agent Problem", Econometrica, 56, pp.1177-1190.

22] Masson, P (1997): "Monsoonal Effects, Spillovers, and Contagion", International Monetary Fund, mimeo.

23] Matutes, C and X. Vives (1996): "Competition for deposits, Fragility and Insurance", Journal of Financial Intermediation, 5, pp. 184-216.

24] Milgrom, P. R. (1981): "Good News and Bad News: Representation Theorems and Applications", Bell Journal of Economics, 12, pp. 380-391.

25] Morris, S and H. S. Shin (1998): "Unique Equilibrium in a Model of Self-fulfilling Currency Attacks", American Economic Review, 88, pp. 587-97.

26] Morris, S. and H. S. Shin (1999): "A theory of the onset of currency attacks", in Agenor et.al (edited) (1999), "The Asian Financial Crisis", Cambridge University Press, Cambridge-New York, 1999.

27] Morris, S. and H. S. Shin (2001a): "Coordination risk and the price of debt", forthcoming in European Economic Review.

28] Morris, S. and H. S. Shin (2001b): "Rethinking Multiple equilibria in Macroeconomic Modelling", NBER Macroeconomics Annual 2000, 139 - 161, MIT Press, 2001.

29] Obstfeld, M. (1986): "Rational and self-fulfilling balance of payments crisis", American Economic Review, 76, pp.72-81.

30] Rogoff, K. (1999): "International Institutions for Reducing Global Financial Instability", Journal of Economic Perspectives, 13.

31] Rose, A. K. and L. E.O.Svensson (1994): "European exchange credibility before the fall", European Economic Review, 38, pp.1185-1216.

32] Sachs, J., A. Tornell, A. Velasco (1996): " The Mexican peso crisis: Sudden death or death foretold?", Journal of International Economics, 41, pp. 265-83.

33] Thomas, J. P. (1999): "Discussion", in Agenor et.al (edited) (1999), "The Asian Financial Crisis", Cambridge University Press, Cambridge-New York, 1999.

34] Wallace, N. (1996): "Narrow Banking meets the Diamond-Dybvig Model", Federal Reserve Bank of Minneapolis Quarterly Review, 20, pp.3-13.